Basic and Applied Research in the Field of Electronics and Communications

Final Report

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Results of the research done under this contract are described in the article s or presented at the meetings enumerated in the attached List of Publications.

Key Words: Atomic physics, Communications, Electromagnetics, Electronics, Lasers, Microwaves, Molecular physics, Quantum electronics, Signal processing.

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Overview of the MIT Research Laboratory of Electronics
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The MIT Research Laboratory of Electronics Joint Services Program is comprised of sixteen work units spanning a broad array of topics in high-speed optics, surfaces and phase transitions, submicron structures, electronic conduction, properties of electronic interconnects, and atomic and molecular physics.

A major emphasis of the work in high-speed optics has been the development of femtosecond optical pulses by means of nonlinear, self-limiting optical properties. These ultrashort pulses have been used as probes of electronic processes, and also in the context of optical signal processing. In addition, they have been exploited in studies of optical interactions with matter, which have led to the observation of new effects with spectroscopic applications.

In the area of surfaces and phase transitions, a balanced program includes both theorists and experimentalists. Theoretical studies have allowed the accurate prediction at atomic-level dimensions of realistic semiconductor surfaces at room temperature, subject to deposition of electronic materials such as aluminum. These theories also account for surface reconstruction among the top monolayers of a substrate lattice. Accurate studies have also characterized phase transitions in chemisorbed systems, and high-resolution x-ray diffuse scattering has been used to experimentally confirm theoretical predictions of surface restructuring, as well as to reveal new phenomena in modelled systems. Unique phases in colloidal crystals have also been revealed experimentally, and a unique apparatus has been built to study chemical reaction dynamics on semiconductor surfaces, thus providing for the first time an accurate characterization of chemical bonding on semiconductor surfaces as a result of common processing procedures such as reactive ion etching.

The JSEP program at MIT has built up a strong submicron structures laboratory which utilizes x-ray lithography to build a large array of structures and electronic devices. One example of the exploitation of this capability is the construction of very narrow field-effect transistors, which show quantum confinement effects, and which have led to a new understanding of electronic conduction in submicron silicon field-effect transistors. In addition to the experimental studies with these devices, a new picture of quantum transport in low-dimensional disordered systems has been achieved. By means of the control of kinetic growth processes, the microstructural evolution of thin-film electronic materials (including both semiconductors and metals) has been extensively studied and characterized with a view toward providing high-quality semiconductor materials, as well as metals with large grain size which are resistant to electromigration. Following the theme of studying the properties of interconnect structures, basic electromagnetic studies of multilayer media have been made in the time domain so that transmission characteristics in complex computer interconnect structures can be precisely understood.

A major thrust of the MIT Research Laboratory of Electronics JSEP program has been fundamental studies in atomic and molecular physics. Recently, with the advent of laser techniques to provide for atom isolation, new experiments have been initiated which are expected to lead to precision measurements of mass and time using these trapped atomic

particles. Our expectation is that improvements in time accuracy of approximately three orders of magnitude will be achieved as contrasted to currently available atomic clocks, which were also invented in the MIT JSEP program. In addition, mass measurements are expected to be improved by at least two orders of magnitude, thus opening many new opportunities in mass spectrometry. These studies have grown naturally from a context of molecular, atomic, and atom field interactions studied over many years in the JSEP program at a fundamental level.

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Degrees Awarded Under Joint Services Support

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Picosecond Optical Devices

Brorson, S.D., M.S., 1985
Dagli, N., Ph.D., 1987
Kesler, M.P., Ph.D., 1988
Kuznetsov, M., Sc.D., 1986
Liu, L.Y., M.S., 1987
Schoenlein, R.W., E.E., 1987
Towe, E.D., Ph.D., 1987
Whitaker, N.A., Ph.D., 1986

Ultrafast Optical & Electronic Processes

No Degrees Granted.

Ultrashort Laser Pulse Interactions with Matter - New Effects and Spectroscopic Applications

No Degrees Granted.

Excitations, Groundstate Properties and Phase Transitions of Surfaces

Kaxiras, E., Ph.D., 1987

Phase Transitions in Chemisorbed Systems

No Degrees Granted.

High Resolution X-Ray Diffuse Scattering

No Degrees Granted.

Graphoepitaxy of Colloidal Crystals

Larson, B.D., Ph.D., 1986

Chemical Reaction Dynamics on Semiconductor Surfaces

Simonson, R.J., Ph.D., 1987

Submicron Structures Technology & Applications

Chou, S.Y., Ph.D., 1986
Yen, A., M.S., 1987

Electronic Conduction in Submicron Si Field Effect Transistors

Licini, J.C., Ph.D., 1987
Stathis, J.H., Ph.D.. 1986

Quantum Transport in Low Dimensional Disordered Systems

Serota, R.A., Ph.D., 1987

Control of Microstructure and Microstructural Evolution in Thin Film Electronic Materials

Maiorino, C.D., M.S., 1986

Electromagnetic Waves in Multilayer Media

Nghiem, S.V., M.S., 1988

Microwave Quantum Optics

No Degrees Granted.

Precision Measurements of Mass and Time Using Trapped Atomic Particles

Flanagan, R.W., Ph.D., 1987
Magill, P.D., Ph.D., 1988
Martin, P.J., Ph.D., 1988
Weisskoff, R.M., Ph.D., 1988

Coherent Atom-Field Interactions in Vapors with Application to New Clock Development

O'Connor, C.E., M.S., 1986
Pevtschin, V., M.S., 1986
Prentiss, M.G., Ph.D., 1986
Zarinetchi, F., M.S., 1986

Study of Phase Conjugate Resonators

No Degrees Granted.

Step Structures in Semiconductor Surfaces - Thermodynamics, Kinetics & Influence on Heteroepitaxy

Abernathy, J.D., Ph.D., 1987

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